A study of the formation and scaling of a synthetic jet

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Funding agency: DoD D-EPSCoR / AFOSR program, 2001-2004

Synthetic jet actuators show good promise as an enabling technology for innovative boundary layer flow control applied to external surfaces, like airplane wings, and to internal flows, like those occurring in a curved engine inlet. The appealing characteristics of a synthetic jet are zero-net-mass-flux operation and an efficient control effect that takes advantage of unsteady fluid phenomena. The formation of a synthetic jet and its subsequent interaction with a larger turbulent flow is only beginning to be understood and a rational understanding of these devices is necessary before they can be applied to the control of flows outside of the laboratory.

The work has two broad **objectives**. The ***first*** is to advance our understanding of how to design and optimize a synthetic jet actuator for maximum jet performance. This objective will be met by investigating the basic fluid dynamics of synthetic jet formation. The experiment (Figure 1) will address the roles of vortex formation and cavity geometry in determining the strength of the jet. The apparatus is designed to study a wide range of conditions giving significantly different flow fields from synthetic jets (Figure 2). This understanding will then be used to meet the ***second objective***, which is an understanding for how synthetic jets control a fundamental flow process. In this case the flow process of interest is boundary layer separation. The second objective will be met through an exploitation of the interaction between a synthetic jet and a turbulent boundary layer. Of particular interest here is the formation and structure of the counter-rotating vortex pair in the boundary layer downstream of the synthetic jet actuator.

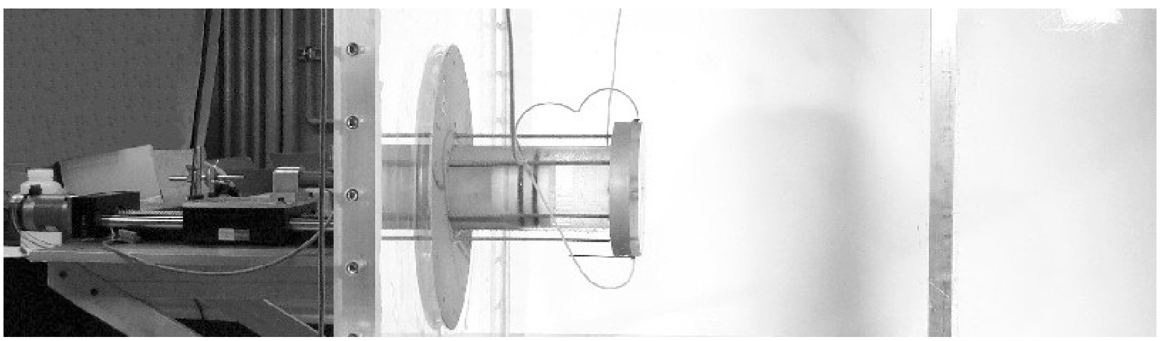
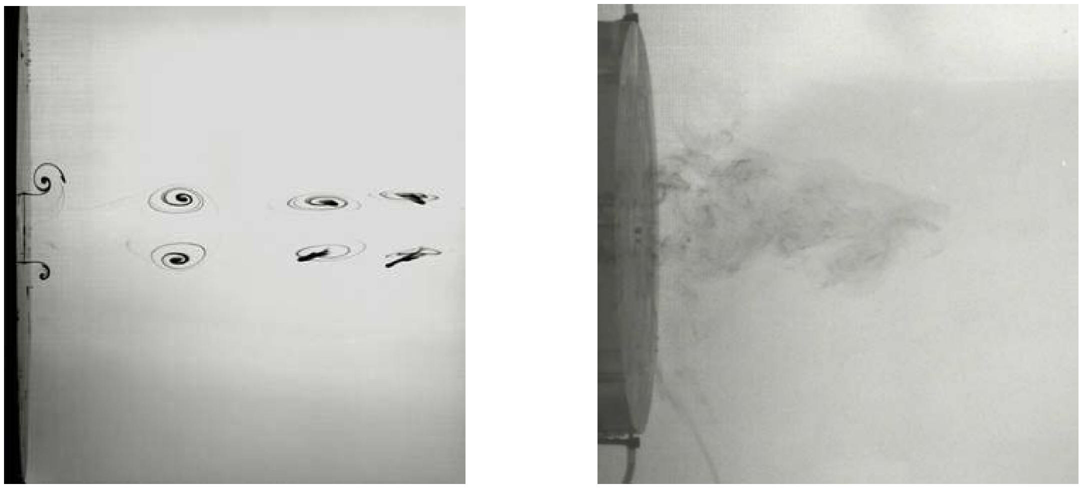


Fig. 1. Large-scale realization of a synthetic jet actuator in water tank at the University of Wyoming.

This study will use an ***experimental approach*** to meet the two objectives. Three experiments are envisioned, each using a liquid as the working fluid. The experiments in the third year at INEEL will use **refractive-index-matching** between the fluid and the actuator material. Refractive-index-matching will allow undistorted optical access to the cavity and the orifice of the actuator. To exploit this optical advantage, laser-based diagnostics will be used to measure the velocity fields.

The study will establish scaling relationships for both the formation of a synthetic jet from different actuator geometries and the interaction of a synthetic jet with a turbulent boundary layer. The study will investigate the structure of the boundary layer downstream of a synthetic jet actuator and will explore the change in this structure as the actuator output is changed. This advanced understanding for how synthetic jets are formed and interact with larger turbulent flows will provide the necessary insight for future designs and numerical models of synthetic jet actuators.



(a) (b)

Fig. 2. Visualization of flow fields induced by synthetic jets: (a) Stroke-to-diameter ratio = 2 and circulation Reynolds number = 500 giving a train of laminar vortex rings and (b) stroke-to-diameter ratio = 1 and Reynolds number = 1000 giving turbulent synthetic jet.